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V. V. Makarov and N. N. Petrov

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# PENETRATION OF 2 TO 11 KeV LITHIUM IONS INTO SILICON CARBIDE SINGLE CRYSTALS

V. V. Makarov and N. N. Petrov

(Leningrad Polytechnical Institute im. M. I. Kalinin)

ABSTRACT

The authors present results of an evaluation made of the penetration depth of 2-11 KeV lithium ions into single crystals of SiC of α-modification. Comparisons are made with the data obtained for the penetration of sodium ions into aluminum and the injection of $H^+$ and $He^+$ ions into aluminum.

It is well known that ion bombardment of luminophors leads to a considerable decrease in the quantum yield of luminescence. When electron excitation of a luminophor, which has been subjected to ion bombardment occurs, the dependence of the luminescence intensity on the electron energy provides the opportunity of evaluating the thickness of the ion-disintegrated layer (provided the path of electrons of a prescribed energy is known in the studied material), which may be assumed equal to the depth of penetration of the bombarding ions into the target. /890*

Such investigations have been preformed with powdered ZnS, CdS, $Zn_2SiO_4$, etc., luminophors ([1-3]). Evaluations were made of the penetration depth of various ions into these materials. However, the roughness of the surface of the powdered specimens (grains, pores) makes the interpretation of the experimental results difficult, particularly at different angles of incidence on the target of the electrons and the ions (as, for example, in [3]), since in this case the electrons may reach sections "screened" during ion bombardment by roughnessess and projections on the surface.

Results are presented below of an evaluation made of the penetration depth of 2-11 KeV lithium ions into single crystals of SiC (α-modification). The specimens consisted of plates with plane-parallel mirror facets (0001). The design of the ion and electron source precluded the possibility of neutral particles falling on the target during ion bombardment and provided equality of angles of incidence of the electron and the ion beams (this angle usually was 30°). In order to increase the intensity of the cathode-luminescence, the specimens were cooled to 77°K. Ion bombardment was performed at 300°K. A detailed description of the experimental set-up is given in [4].

*Numbers given in the margin indicate pagination in original foreign text.

Figure 1 shows the dependence of radiation $I_f$ (wavelength, 5200 Å) on the energy $E_e$ of the luminescence-exciting electrons during the bombardment of the crystal by lithium ions of different energies. In all cases, the radiation dose amounted to about $10^{16}$ ion·cm$^{-2}$. The curves in this figure make it possible to compare the electron and ion penetration depths into the specimen studied. Thus, for example, 11-KeV lithium ions penetrate into SiC to the same depth as 3-KeV electrons.

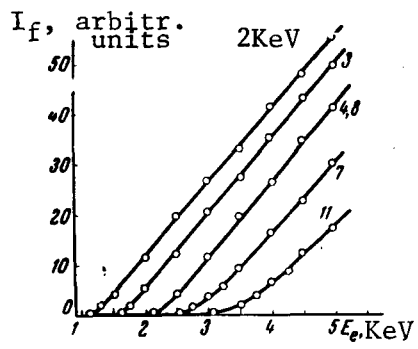


Figure 1. Dependence of the cathode-luminescence intensity on the energy of exciting electrons after crystal bombardment with lithium ions of different energies. The numbers at the curves — $E_0$ in KeV.

In order to determine the numerical value of the ion path, it is necessary to know the dependence of the electron penetration depth on their energy. The authors utilize the data of [5] on electron penetration through thin silicon films. The results of this work are approximated by the formula

$$R_e = 425E_e^{1,4},$$

where $R_e$ (Å) is the electron path with an initial energy $E_e$ (KeV) in the silicon.

A determination according to the points of intersection of the curve $I_f$ ($E_e$) by axis $E_e$ (Figure 1) of the threshold energy $E_{th}$ of the electrons and employment of the formula given above make it possible to calculate the penetration depth $R_0$ of lithium ions in SiC (assuming the electron paths with an identical initial energy do not differ greatly for Si and SiC). The results of these calculations are presented in Figure 2, In plotting in a double logarithmic scale, /891 the points obtained fall satisfactorily on the straight line with the tangent of the angle of inclination equal to 0.77. Therefore, the relationship shown in Figure 2 may be presented analytically in the form

$$R_0 = 350\ E_0^{0.77},$$

where $R_0$ (Å) is the path of the lithium ions with an initial energy $E_0$ (KeV) in silicon carbide. If the quantity $E_p$ is determined from Figure 1 by means of extrapolation of the linear segments of the curves with zeroth value $I_f$, the character of the relationship $R_0 \sim E_0^{0.77}$ is retained, whereas the coefficients of proportionality increase only by 20%.

The path values obtained exceed by several times the value obtained in [6] for the penetration of sodium ions into aluminum, and are extremely close to the data of [7] for the injection of $H^+$ and $He^+$ ions into aluminum, where a value

of $R_0 \simeq 200\ E_0^{0.83}$ was obtained. Calculations by means of the Bohr-Nielsen formulas [8] (considering the average nuclear charge of the bombarding substance equal to 10, and the average atomic weight equal to 20) yield path values of $Li^+$ in SiC considerably lower than those obtained from Figure 2. Evidently, these formulas in this case are not applicable since a substantial deviation of the relationship $R_0\ (E_0)$ from the linear testifies to the fact that an appreciable part of the energy is expended by the bombarding particle on the ionization of the atoms of the solid. However, it is not possible to reach final conclusions in this respect, since the form of the relationship $R_e\ (E_e)$ for SiC is not known exactly.

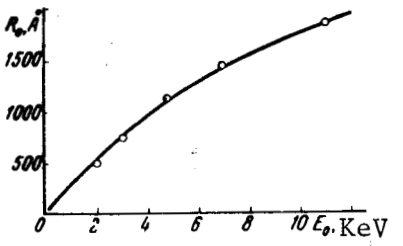


Figure 2. Path-energy curve for lithium ions in silicon carbide

In conclusion, the authors express their gratitude to M. A. Yeremeyev for useful discussions, as well as to M. B. Reyfman for kindly providing the single crystals of silicon carbide.

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